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# FOREIGN TECHNOLOGY DIVISION
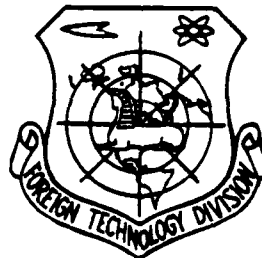
ENCAPSULATION OF ELECTRONIC SUBASSEMBLIES
WITH THERMOSETTING RESINS.  PART I

by

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# ENCAPSULATION OF ELECTRONIC COMPONENTS
## WITH THERMOSETTING RESINS. PART I

### Pawel Pozdziel

## Methods of encapsulation

Methods of encapsulation with thermosetting resins
can be divided both with respect to the type of resins used and
with respect to the encapsulation technology applied. To some
degree these encapsulation technologies include formally the
following: *

    a) overflow pouring in cups

    b) overflow pouring in forms

    c) dip-coating

    d) molding in liquid resin

    e) coating in fluidized bed

    f) the E-PAK method.

Whereas the first three technologies use many types
of resins: silicon , polyester, polyurethane, hydrocarbon, acrylic -
and exceptionally in the case of dip-coating also phenol-formaldehyde -
the epoxy resins being the dominant but not overwhelming material,
in the case of last three technologies the epoxy resins are used
nearly exclusively.

When we talk about resins we consider in reality compositions

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\* Pressure casting is treated as a separate technology.

containing several components, for instance, the resin proper,
a hardener, a filler, an accelerator, elasticizing additive
(plasticizer), a diluent, etc. Each of these components may be
of many types, hence the number of compositions and their variants
used in electronics reaches many thousands.

For c), e) and f) technologies a rather narrow group
of special commercial products has been developed; these products
serve often exclusively for encapsulation of subassemblies.

Before we start describing particular technologies of
encapsulation, it is necessary to discuss the problem of purity
of resins applied in these processes.

## Poisoning of semiconductor elements by components of plastics

For many years there has been a controversy whether
the use of plastics still enables to reach an appropriate level
of dependability and stability of semiconductor devices. Numerous
investigations of reasons for differences in stability and
dependability between semiconductor devices encapsulated in metal
materials and those encapsulated in plastics led to the conclusion
that one of the basic causes of these differences is the presence
of ionic impurities. Selection of plastics not containing such
impurities can reduce considerably, or even totally eliminate,
differences in dependability of both these types of subassemblies.

The mechanism of poisoning may be various. Under the
influence of the boundary electric field, existing in the area
of polarized semiconductor junctions, there can occur migration

of ions from agents contaminating the encapsulating plastic and
formation of a space charge /1, 2/. At an elevated temperature,
which in the case of use of silicon transistors may reach 175 °C,
the number and mobility of ions in plastic increase strongly
which leads to further growth of the space charge. The boundary
electric field causes separation of ions in such a way that positive
ions accumulate at the negative edge of field, and negative ions
/3/ at the positive edge (Figure 1).

It follows from the method of work of transistor that
polarization potential remains even when the device becomes cold
between the periods of work. Under these conditions, the accumulated
space charge remains at least partly frozen and behaves as a layer
(cover) of condenser; the second layer is provided by a charge
accumulated in semiconductor in the vicinity of junction of
impoverished region. We deal here with the so-called phenomenon
of surface inversion or channelling. The presence of such a condenser
can exert basic influence upon the work of transistor, changing
characteristics of the junction.

The largest change is shown in amplification coefficient $\beta$
whose value may drop even below the unity. From the knowledge of
oxidizer density ($SiO_2$) and the location and level of impurities
one can calculate the size and density of charge necessary to
cause the surface inversion.

It was found /3/ that it suffices to have only a $10^5$-
impurity in one place to cause the described electrical phenomena.

It means that the density of charge on the surface equal to 1 ppm
may cause surface inversion. It is also possible to have the transfer
of electrons through the oxide layer. The presence of impurities
may cause also sometimes an increase of the barrier current
(Table 1) of semiconductor devices (e.g., microdiodes), and after
exceeding a certain level of impurities there may occur an inversion
of semiconductor phenomena /4/. It was also established that the
ratio of aliphatic to aromatic groups in encapsulating plastics
has an effect upon the character of semiconductor areas /4/.
The presence in resin of a larger number of aromatic groups causes
attraction of electrons and formation of a surface close to p type,
and of a smaller number - to n type. The reverse is the case when
the resin contains a larger number of aliphatic groups, since
then we have a surface of n type /10/.

Negative effects of space charge caused by impurities
/5/ were found in investigation of transistors type MOS /10/
covered with epoxy resin as well as various types of silicon resins.
Only transistors covered with silica gel, characterized by the
smallest number of impurities, did not show damage after 1000 hours
of work.

Investigations carried out by Fairchild company
on transistor TBX-125HB, encapsulated with epoxy resins of
various compositions, have shown that the most sensitive parameter
suitable as a criterium for the level and effect of impurities
contained in the resin is the coefficient of amplification ß
at the temperature $125^{o}C$ at $10 \mu A$ $h_{FE}$ and reverse polarization
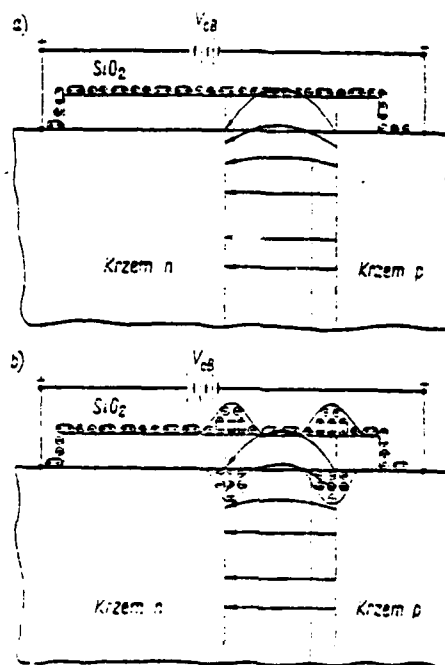
Figure 1. Mechanism of the degradation of semiconductor caused by the presence of impurities in encapsulating plastic.

        a - formation of boundary field;

        b - polarizing effect of impurities.

                (Krzem = silicon)

potential 40 $V_{CB}$, measured after a long work of the transistor. The reason for change of $\beta$ , in addition to accumulation of space charge, would be here also penetration of small alkali ions (Na + K) through the $SiO_2$ layer.

Table 1. Impurities occurring in components of epoxy resins.

| Component type | Agents appearing in synthesis |
|---|---|
| Epoxy resin | Epichlorohydrin, dichlorohydrin, allylohydrin, propylene, sodium hydroxide, dian, acetone, benzene, phenol, catalyst, sodium orthosilicate |
| Hardeners | Ethylenediamine, diethylenetriamine, polyaminoamides, acid anhydrides |
| Fillers | $Al_2O_3$, $SiO_2$, $CaCO_3$ |
| Pigments | $TiO_2$, soot, $CaCO_3$ |
| Solvents | Ketones, esters, ethers, hydrocarbons, chlorinated hydrocarbons, alcohols |
| Agents increasing fluidity | Company formulations, urea, etc |
| Fire retardants | $Sb_2O_3$, chlorinated and brominated resins |

| potential impurities in resin |
| --- |
| $Cl^-$, $HOCl$, $Na^+$, $OH^-$ |
| $-C_6H_4-OH$, $(CH_3)_2C=O$, |
| $C_6H_6$, $H^+$, $Br^-$, $C_6H_5O^-$, |
| $CO_2$, $H_2O$, $CO_3^=$, $SiO_4$ |
| $NH^+$, $Cl^-$, $NH_3$, $H^+$ |
| $RCOO^-$, $R(COO^-, H^+)_2$ |
| $Al$, $Si$, $CO_3^{2-}$, $Ca^{++}$ |
| trace metal ions |
| $Ti^{4+}$, $C$, $Ca^{2+}$, $CO_3^{2=}$ |
| $R_2C=O$, $RCOO^-$, $H^+$, $Cl^-$ |
| $ROR$, $ROH$, $C_6H_5CH_3$ |
| $NH_4^+$, $NH_3$, $H_2O$, $CO_3H^+$ |
| $Sb^{3+}$, $Cl^-$, $Br^-$ |

Table 1.  Continued.

Impurities having negative effect upon semiconductors may originate, among others, from unreacted hardeners and accelerators or components used for synthesis of epoxy resins (e.g., epichlorohydrins). It was found that the effect of amine accelerators is considerably greater than the effect of organometallic accelerators (Figure 2). A lesser effect of impurities was noted when using multifunctional anhydrides as hardeners, e.g., quatrofunctional anhydride of benzophenone acid. This highly reactive hardener does not require amine accelerators and causes dense cross-linking which hampers mobility of ions. The use of purified, densely crosslinking benzophenone anhydride practically eliminates totally the negative effect of impurities which are usually found in commercial epoxy resins (Figure 3).

The choice of plastic containing the minimal amount of harmful impurities becomes easier when we consider the source of their origin:

- from accidental impurities in semiproducts used in the synthesis, from the production equipment,

- from additives introduced in the course of production, such as catalysts, emulsifiers, etc., which are later difficult to remove completely,

- from components added to modify certain properties of ready plastic, e.g., fillers, fire retardants, antioxidants, etc.[*]

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[*] For instance, high-pressure polyethylene polymerized without the use of catalysts contains less impurities than the catalytically-obtained low-pressure polyethylene.
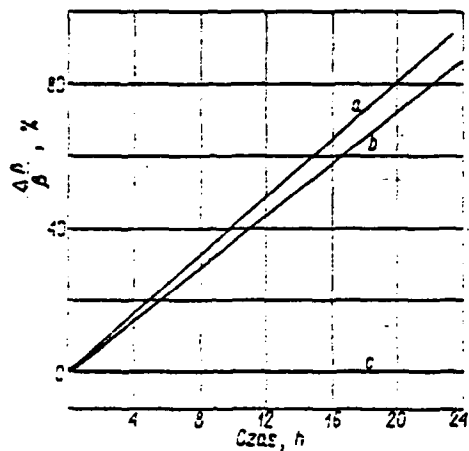
Figure 2. Effect of accelerators on stability of transistors
encapsulated in plastic:
a- curing agent D (Shell); b - BDMA; c - organometallic salt
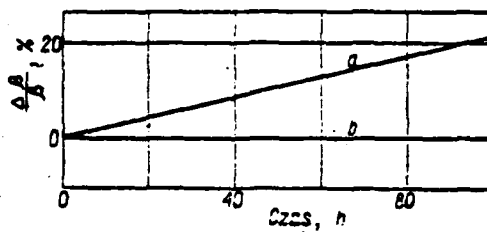(Czas, h = Time, hours)



Figure 3. Effect of the purity of hardener (benzophenone anhydride)
on stability of encapsulated transistors:
a - technical; b - purified.

Table 1 lists impurities whose occurrence could be expected in various components of epoxy formulations.

Additional purification of resin and hardeners, e.g., through redistillation or molecular distillation, removes the major part of impurities which eliminates to a considerable degree the discussed harmful phenomena. It was found that not only is the absolute concentration of inorganic impurities important but also is their way of combining with the resin and their solubility in the composition. E.g., if the usually very harmful chloride ion is combined with epoxy resin through covalent bond, its negative effect is felt only at the temperature $150^\circ C$ when it separates from the resin (Figure 4).
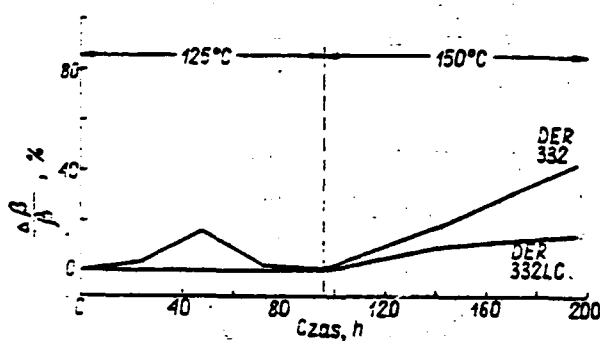


Figure 4. Effect of the presence of chlorides on stability of transistors encapsulated with epoxy resin. DER 332 - ordinary resin; DER 332LC - resin with reduced contents of chlorides.
(Czas, h = Time, hours)

When we have impurities difficultly soluble in resin the concentration of "wandering ions" is in reality smaller than the total concentration, and negative effects of their presence are smaller. A special choice of the components of formulation is, therefore, necessary in order to carry out properly the encapsulation of semiconductors. As was said before, especially purified resins and hardeners should be used (Table 2 and Figure 4). It is also important that there should not remain mobile ions after the hardening, and that the ratio of hardener to resin should be close to the stoichiometric one (Table 3). Fillers and other additives possibly should be difficultly soluble and difficultly dissociating compounds of high purity.

It was found, for instance, that the surprising negative effect of $SiO_2$ filler - so inert with respect to silicon - will not be seen if it is treated previously with boiling water to leach out impurities from $SiO_2$ (Figure 5). On the other hand, certain fillers such as some varieties of Lewis acid type ($SiO_2Al_2O_3$) are even capable of adsorbing or immobilizing some impurities contained in compositions, such as amine groups from hardeners and accelerators, and thereby may prevent drop in the value of the coefficient of amplification (Figure 6).

Harmful effect of impurities on semiconductor devices may result (and in some cases may be the main reason) from the corrosive electrochemical action of ionic impurities on thin metallic layers, particularly Al, on the surface of semiconductor /6, 11/. Here typical are two effects: closing and opening of

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Table 2.  Results of spectrographic analysis of
plastics used for encapsulation [19].

| plastic | Form | Detected metals | Order of conc. of imp., % |
|---|---|---|---|
| Epon 828 | As delivered | Cu, Al, Mg, Si, CaSi | $10^{-2} - 10^{-1}$ |
| Epon 828 | Residue after dist. | Ca, Mg, Al, Fe, Cu, Cr, (Si - 0,5) | $10^{-2} - 10^{-1}$ |
| Epon 828 | Distilled resin. | Cu | $10^{-2} - 10^{-1}$ |
| Sylgard 182 | Hardened | Si, Ti, Mg | $10^{-2} - 10^{-4}$ |
| Silicon coating DC-644 | Hardened | Cu, Mg, | $10^{-2} - 10^{-1}$ |
|  |  | Zn | $10^{-2} - 10^{-4}$ |
| Silicon casting DC-305 | Pressed | Cr | $> 5\%$ |
|  |  | Pb, Ti, Ni, Cu, Mn, Al, Mg | $10^{-2} - 10^{-1}$ |
|  |  | Fe, Co | $0,1 - 0,5$ |
| Silica gel | Hardened |  | Not found |
| Phenolic casting | As delivered | Ca | $> 5\%$ |
|  |  | Mg | $0,1 - 0,5$ |
|  |  | Fe, Si, Na | $10^{-2} - 10^{-1}$ |
| Teflon | Baked emulsion | Cu, Mn, Al | $10^{-2} - 10^{-4}$ |
| Teflon FEP | Baked emulsion | Cu, Mg |  |
| Teflon | Pressed forms | Cu, Ti, Mg |  |
|  |  | Ti | $10^{-2} - 10^{-4}$ |
| Teflon FEP | Pressed forms | Cu, Ti, Mg |  |
| Kynar | Baked emulsion | Ti, Cu, Mg |  |

Table 3. Effect of temperature on barrier current
of diodes encapsulated with various plastics.

| Type of encapsulating plastic | Value of barrier current in $\mu$A at 50 v | | |
|---|---|---|---|
| | Initial | After 20 hours at $150^\circ$c at reverse potential 75 v | After 20 hours of additional stay at $150^\circ$c without potential |
| Epoxy, purified, stoichiometric | 10 | 548 | 14 |
| Epoxy, purified, nonstoichiometric | 9 | $10^4$ | $10^4$ |
| Epoxy, technical, stoichiometric | 12 | $23.7 \cdot 10^4$ | $12.1 \cdot 10^4$ |
| Epoxy, technical, nonstoichiometric | 12 | $3.1 \cdot 10^4$ | $1.4 \cdot 10^4$ |
| Teflon FFP | 17 | 18 | 16 |

the circuit. The first of them (Figure 7) appears in the area
of anode in which, as a result of the action of $Cl^-$, $NH_4^-$,
$Cu^+$ and $Fe^{3+}$ ions, there is the depassivation of aluminum
layer, its dissolution, and formation of an $Al_2O_3$ insulating
layer. In the case of metallization with gold, there can be
deposition on anode of gold ions originating from the disso-
lution of cathode ($Au$ $Au^{3+} + 3e$), causing the shortening of
the circuit (Figure 7).

Defects caused by electrocorrosion are accompanied by
other negative phenomena consisting of the appearance of shifted
break path. This is caused by the occurrence of high-resistance
bridges in places where can be shorting and deposition of $Au$,
resulting in moving (shifting) of side path.

Finding of the occurrence of impurities in epoxy compo-
sitions has caused that, despite their many advantages, there is
the tendency of some producers to abandon the application of
epoxy resins for encapsulation of professional semiconductor
devices and rather to use plastics with smaller contents of
impurities, primarily the silicon resins. Encapsulation with
fluorine plastics (Teflon, Kynar) is not widely used because
of technological difficulties, despite the fact that they
contain little impurities and do not pose the associated
problems. A solution is the application of plastics with small
contents of ions as an intermediate layer between the epoxy
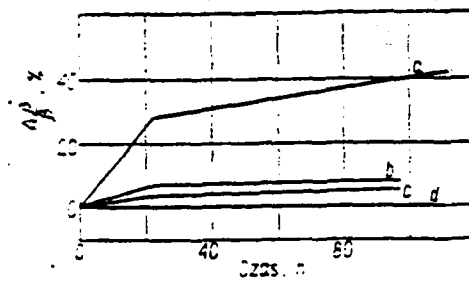resin and the junction. It applies, in particular, to silica gel

Figure 5. Effect of the purity of $SiO_2$ on stability of transistor encapsulated with epoxy resin:

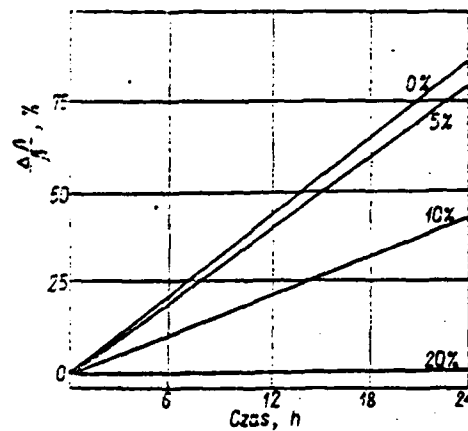a - $SiO_2$ not leached; b - leached; c - $SiO_2$ of high purity; d - model.



Figure 6. Effect of concentration of ion-adsorbing filler ($SiO_2Al_2O_3$) in encapsulating epoxy resin on stability of transistor.
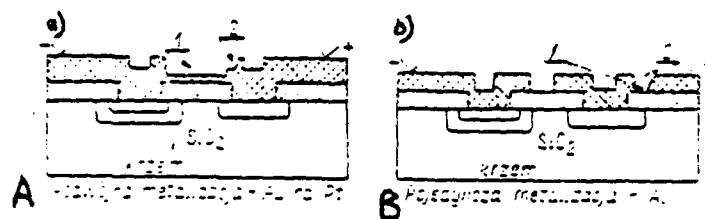
Figure 7. Corrosive action of impurities contained in encapsulating
plastic on integrated circuit:
a - closing (shorting); 1 - area of dissolved metal; 2 - shifted
current path; b - opening of circuit; 1 - circuit opening;
2 - insulating products of corrosion.

        A - double metallization - Au on Pt

        B - single metallization - Au

           (Krzem = silicon)

which, in addition to the fact that it contains the smallest number
of impurities, relieves pressures thanks to its elasticity.

Many studies /7/ indicate that there are possibilities
of such a choice of components of epoxy formulations that their
action on semiconductor is no greater than the effect of silicon
resins. This problem is very important in view of many advantages
enjoyed by epoxy resins in comparison with silicon resins, such as
better adhesion, better chemical stability and larger mechanical
strength. In particular, we have here in mind strongly-crosslinked
resins, such as epoxy-novolaks (DEN-438, DEN-439, Dow Chemical,
TCN 1235, 1273, 1280, 1299-CIBA).

In densely-crosslinked epoxy-novolak resins the ions contained in resin remain entrapped in the space network, and their mobility in electrical field is considerably reduced so that the previously described negative effects are largely eliminated. Moreover, epoxy-novolak resins exhibit also a number of other advantages. One of the most important of them is an increase of the glass temperature ($T_g$) to $150^{\circ}C$, hence by 20-30 $^{\circ}C$ higher than in the majority of dian resins employed now for encapsulation of electronic subassemblies. An increase in $T_g$ means an increase of temperature at which the mobility of ions increases, and at which we have a sudden increase of the coefficient of thermal expansion ( $\alpha$ ) causing the appearance of strains and possibility of damage to subassemblies. It was found, for instance, that $\alpha$ of epoxy resin, which below the glass temperature is $22.5 \times 10^{-6}/^{\circ}C$, increases more than three times to the value of $75 \times 10^{-6}/^{\circ}C$ after passing $T_g$. Other advantages of epoxy-novolak resins include a smaller secondary contraction, high mechanical strength, small absorption and permeability of moisture, and larger thermal conductivity. So far, epoxy-novolak resins have found main application for castings and fluidizing powders. Their application in pouring technology is limited by high viscosity. In some cases they are stable at room temperature. Nevertheless in cases where thermal resistance permits to apply hot pouring, their use in encapsulation technology in cups or forms improves considerably the work of subassemblies.

In any case, the controversy whether to encapsulate professional semiconductor devices with plastics has been definitely settled. The investigations are going on merely whether it is more advantageous to use silicon resins or epoxy resins.

## Pouring in cups and forms

Technologies of pouring in cups and forms are of general character, and they can satisfy a broad range of requirements for environmental protection and other additional demands. In contrast to moldings, here the absence of lubricating agents ensures a better adhesion of resin to leads and subassemblies. These technologies can be applied to small, medium and large-scale production, although in the last case they are seen less and less often. However, in encapsulation of large-size assemblies these technologies continue to dominate and are irreplaceable (Figure 8).

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The same compositions are used for both technologies. If formulations are very elastic, such as for instance silica gel, it is necessary to use cups as mechanical shields.

The most suitable technology for large-scale production is the use of cups. Moreover, this method ensures also the mechanical reinforcement, placing of the flooded element in the middle of protective layer the part of which is being formed by the wall of the cup and also an esthetic appearance of the subassembly.

An intermediate technology is the application of multi-use cups of polypropylene or TPX, the materials for which the resins show no adhesion (Figure 9). The price of injected cup

Figure 8. Encapsulation of a large electronic assembly with silicon resin of Sylgard type (the photograph obtained through courtesy of the Dow Corning Company).

comes merely from several to several tens of gros$s$, so that even at low-scale production it is more profitable than making a larger number of metal forms, particularly that the cup may be used hundred times or more. True, it is necessary to have injection mold to produce cups; however, this mold may be of a simple one-nest type, and its life is practically unlimited. Another solution aiming at cost reduction is the use of multi-nest molds from elastomers - mainly from silicon rubbers, and lately also more and more often from elastic polyurethanes or types obtained by vacuum forming from sheets. Metallic forms are now used less
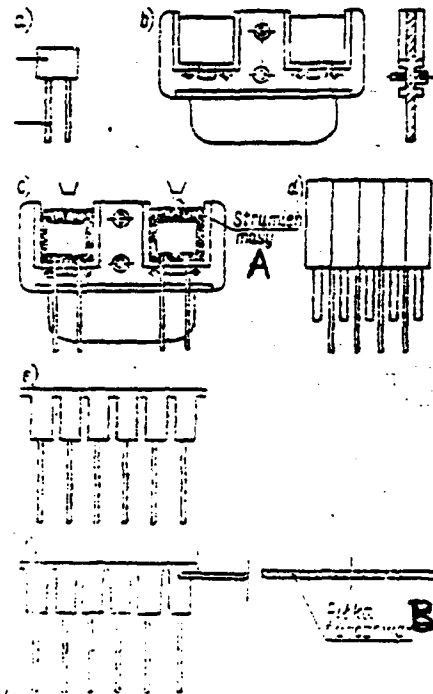
Figure 9. Encapsulation of electronic subassemblies by the
method of pouring into multi-sectional polypropylene form.

        a - nonencapsulated condenser

        b - segment of polypropylene form

        c - pouring on condenser placed in polypropylene form

        d - form with flooded condensers

        e - mold with flooded condensers

        f - cutting off the top of mold and separation
           of encapsulated condensers

        A - stream of mass (resin)

        B - circular saw

and less often, mainly in pouring on large assemblies in small-scale production, and less frequently in middle-scale production. As was mentioned before, the compositions for pouring are generally prepared by the user in his own way, which makes the process quite flexible and enables to adopt compositions suitable for individual requirements of subassemblies as well as for the character of production. However, it is very tedious and labor-consuming to weigh the components in defined proportions, and to do their mixing and degassing, particularly putting small doses into millions of miniature cups, as it happens in large-scale production.

Many arrangements have been developed to reduce this labor consumption. Depending on the production scale, these arrangements range from simple ones such as manual control of dosimeters, injectors, supply pumps, guns, etc., to programmed automatic machines (Figure 10). These machines simultaneously mix the components, degas the composition, heat it, and pour /556 into cups the required amounts with needed accuracy. Their output reaches several thousand subassemblies per hour.

The basic technological requirements put before the compositions for pouring are the smallest possibly viscosity, small exothermicity, a low temperature (possibly room temperature), a short time of hardening, and the long lifetime of the composition.

The majority of these requirements are difficult to meet while attempting to fulfill the requirements concerning the physical and chemical properties put before the compositions.
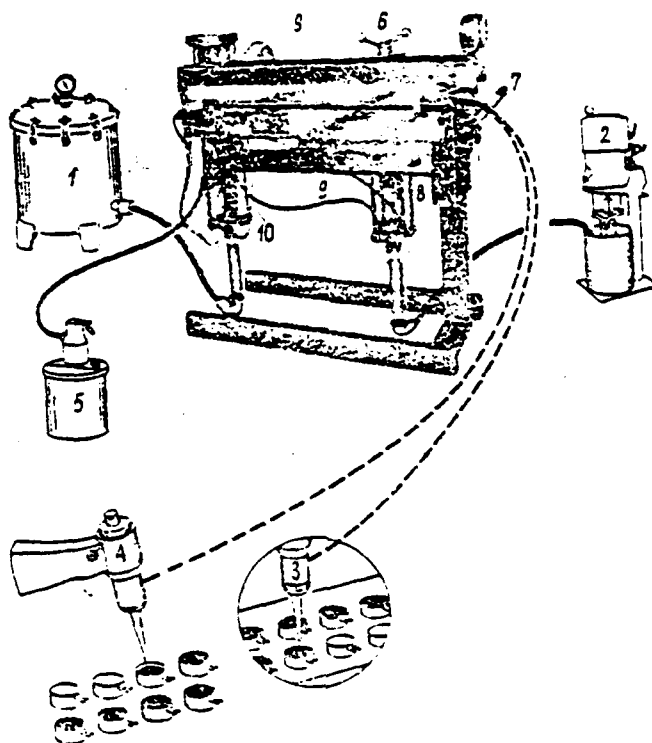
Figure 10. A system for semi-automatic encapsulation of electronic subassemblies by pouring:

    1 - resin; 2 - hardener; 3 - manual dosing;
    4 - automatic dosing; 5 - solvent; 6 - regulator of the
        ratio of components; 7 - a system measuring the
        components; 8 - dosing press; 9 - switch for
        continuous pouring; 10 - dose regulator.

Thus, for instance, a low viscosity entails generally a large contraction hence large strains, worse electrical properties, fragility and poorer thermal conductivity. Similarly, the very desirable hardening at room temperature does not ensure obtaining the optimal electrical properties.

The problem of the choice of components of formulation for pouring has already been dealt in detail /8, 9/. Here we shall discuss only the group of compositions characterized by large transparency.

Together with development of electronic optics and production of such subassemblies as emission diodes, photodiodes, phototransistors, digital lamps, etc., there arose the need to develop compositions for encapsulation which would be characterized by a small, and in some cases selective, absorption of visible light. Of course, if we have at our disposal a resin which transmits well the visible light (minimum 90%), it is easy to achieve selective absorption by introduction of soluble dyes into the resin. Among thermosetting resins used for various purposes the following resins show large transparency:

- stiff silicon resins,
- elastic silicon resins (e.g., of Sylgard type),
- acrylic resins,
- allylic resins,
- polyester resins.

Unfortunately, none of these resins fulfills all the requirements put for encapsulation of subassemblies. Stiff (hard) silicon resins are too fragile, require a high temperature for hardening and have a high contraction. Transparent silicon resins of Sylgard type are too soft and vulnerable to scratching. Polyester, allylic and acrylic resins show excessive contraction and, on the whole, have insufficient electrical properties. All these mentioned plastics exhibit poor adhesion to the majority of materials. Although in some cases the application of the above mentioned resins cannot be excluded, the best results are obtained using transparent epoxy resins especially developed for this purpose. These resins are produced by several specializing companies which supply materials for electronic industry (Table 4). These are compositions of low viscosity 400-3000 cp, hardened in the range 88-125°C after 4-24 hours. They show large transparency (Figure 11) in the region from 3000 Å to 7000 Å, and some even up to 26 000 Å. Their transparency is not changed after prolonged work at 90-125°C, and for a short time even at the temperature 175°C. The pouring technology does not differ from that with other epoxy resins except for some extra precautions to avoid the occurrence of scratching, blotting or other faults which could deteriorate the transparency. It is necessary to use forms (molds) of silicon type RTV, Teflon, polypropylene or TPX; and if steel forms are used they should be covered with Teflon coating or covered with baked layer of silicon lacuer. Dyes can be

Table 4.  Properties of epoxy resins with high transparency used in electronics.

| property | Hysol C 75 Std | Hysol C 74 Std | Maraglass 655 | Maraglass 658 | Stycast 1269 A |
|---|---|---|---|---|---|
| Viscosity, cP | 2500 | 200 | 500 | 3000 | 4000 |
| Gelling time, hours | 24 — 48 | 24 — 48 | 24 | 1 | |
| Hardening, hours/°C | 16/100 | 16/100 | 8/110 | 24/25 | 16/88 |
| Contraction, % | 0,02 | 0,02 | — | — | 0,6 |
| Hardness, °Sh | D-84 | D-84 | D-85 | D-82 | D-85 |
| Water absorption, % | 0,1 | 0,1 | — | — | 0,1 |
| Deformation temperature, °C | 150 | 145 | 50 | — | 125 |
| Thermal conductivity, cal/cm.sec.°C | 0,00047 | 0,00035 | — | — | 0,00065 |
| Expansion /°C | $70 \cdot 10^{-6}$ | $70 \cdot 10^{-6}$ | — | — | $70 \cdot 10^{-6}$ |
| Strength to bending, $kG/cm^2$ | 690 | 690 | — | — | 2310 |
| Strength to pulling, $kG/cm^2$ | 350 | 400 | — | — | — |
| Elongation, % | 1,4 | 1,6 | — | — | — |
| tg δ | | | | | |
| 1 kHz | 0,01 | 0,01 | 0,02 | 0,03 | 0,0054*) |
| 10 kHz | 0,012 | 0,012 | — | — | |
| 100 kHz | 0,005 | 0,005 | — | — | |
| ε : | | | | | |
| 1 kHz | 3,5 | 3,4 | | | |
| 10 kHz | 3,4 | 3,3 | 4 | 4,19 | 3,8*) |
| 100 kHz | 3,3 | 3,2 | — | — | |
| Resistivity, Ω cm | $8 \cdot 10^{13}$ | $2 \cdot 10^{15}$ | — | — | $7 \cdot 10^{14}$ |
| Refraction coefficient | — | — | 1,55 | 1,53 | 1,54 |

*) frequency $10^6$ Hz

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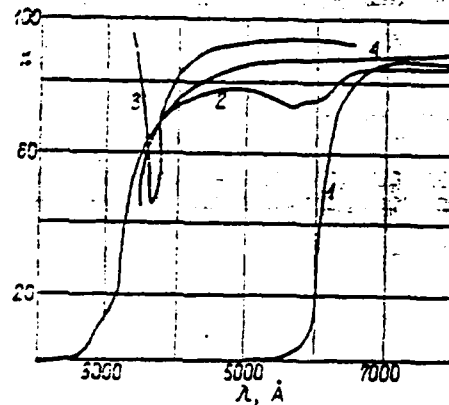


Figure 11. Light absorption curves of epoxy resins used in optoelectronics:

1 - MC 18 clear; 2 - MC Red; 3 - C 74 std, C 75 std;
4 - Stycast 1269 A.

introduced into the resins directly or in suitable solvents, such as dibutyl phthalate. The hardening should be carried out by convection in a dryer without the circulation of air, which could bring small particles of dust or cause surface faults in the form of circular lines. In addition to high-transparency resins for pouring, highly transparent epoxy moldings are also produced for optoelectronics.

An example of such a molding is Hyflo MC 18 made by Hysol Company in colorless or red form. This product has the fluidity 75-112 mm (measured by the spirals method according to ЦМI-1-66), is characterized by a small content of impurities

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(Cl 0.45%; and K, Na, Mg and Cu less than 0.0005% each), has glass temperature $120^{\circ}C$, strength to pulling 560 kG/cm$^2$, strength to bending 1050 kG/cm$^2$, hardness $35^{\circ}$ Sh, contraction 2%, and thermal expansion 65 x $10^{-6}/^{\circ}C$. The contraction and thermal expansion of this product are, of course, higher than those of the newest filled epoxy-novolak moldings (0.5% and 30 x $10^{-6}/^{\circ}C$ respectively) which are used for encapsulation. However, these values are not so much higher as to cause damage to encapsulated subassemblies.

The pressing is carried out under the pressure 4-70 kG/cm$^2$ at the temperature 145-171 $^{\circ}C$ for 4 minutes. Additional hardening at $150^{\circ}C$ takes 4 hours.

When the shapes are more complicated, the pressing is carried out in the form nests, to which vacuum is applied during pressing. Actually, the pressing with nonfilled transparent resins can, in principle, be already classified as belonging to the next described technology, which will be discussed in part II.